GC51D-0831: A Study of the Impact of Dams on Sediment Retention in the Mekong River Basin

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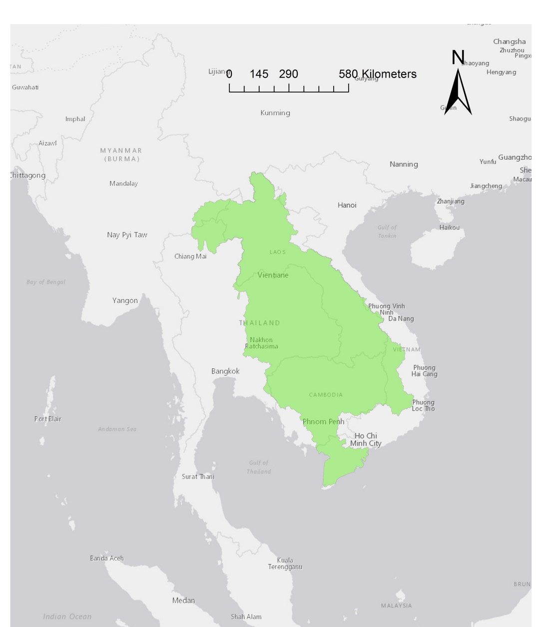
Abstract

Dam construction in the Mekong Basin has many cascading effects on the ecology, economy, and hydrology of the surrounding region. The focus of this study is to utilize the Soil Water Assessment Tool (SWAT), developed at Texas A & M, a rainfall-runoff hydrologic model to determine change in sedimentation in the Mekong Basin after the construction of dams. This study uses land cover land use and reservoir datasets created by the NASA SERVIR-Mekong Regional Land Cover Monitoring System and Dam Inundation Mapping Tool as inputs into the model. The study also builds on the capabilities of the SWAT model by using the sediment trapping efficiency (STE) equation from Brune (1953), rewritten by Kummu & Varis (2007), to calculate STE of dams and estimate change in sediment concentration downstream. The outputs from this study can be used to inform dam operation policies, study the correlation between dams and delta subsidence, and study the impact of dams on river fisheries, which are all pressing issues in the Mekong region.

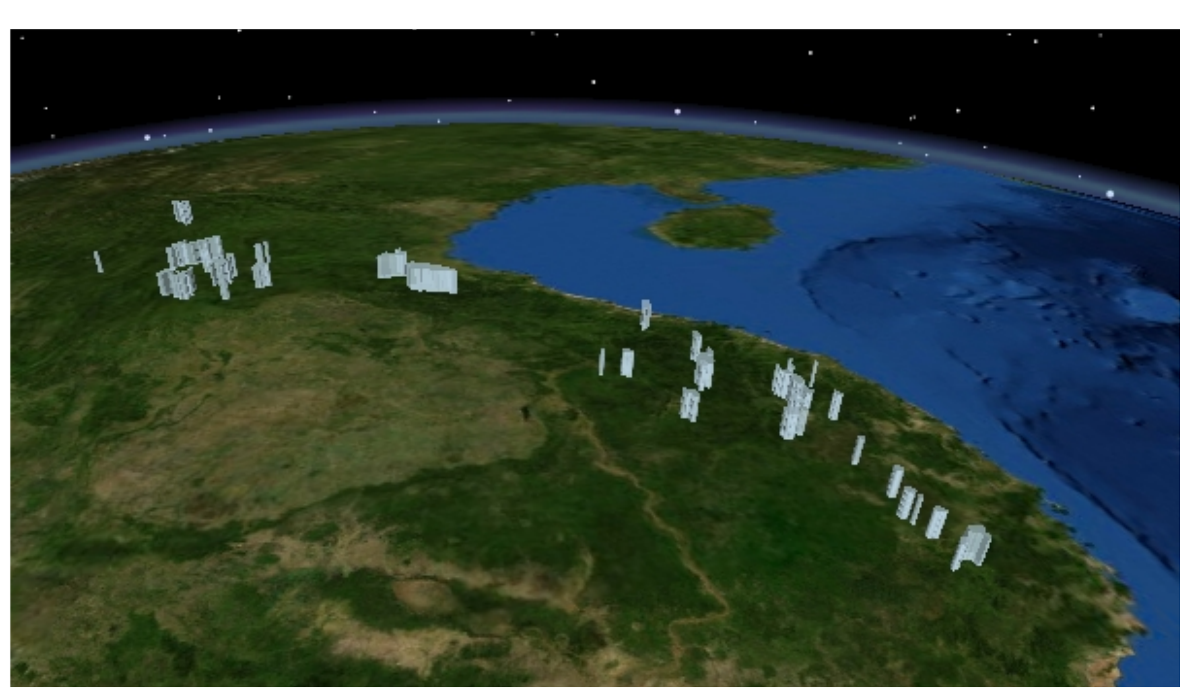
Objectives

- Perform hydrologic modeling of Lower Mekong Basin from year 2000 to 2017 to simulate pre-dam construction scenario
- Estimate wet season and dry season storage capacities for reservoirs in the Lower Mekong Basin constructed after year 2000
- Estimate theoretical sediment trapping efficiency of reservoirs in the Lower Mekong Basin constructed between 2000 and 2017
- Estimate potential sediment trapping of planned reservoirs

Study Area

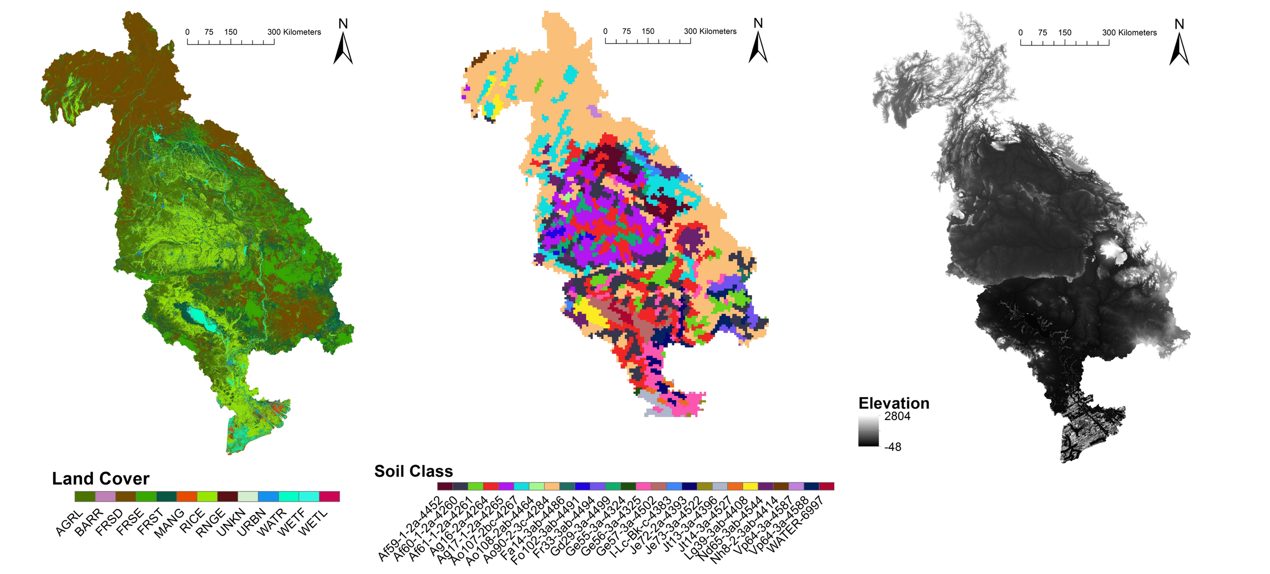


- Lower Mekong River Basin (LMB) in Southeast Asia
- Includes Thailand, Vietnam, Cambodia, Laos, and Myanmar
- 800,000 km^2 dominated by forest cover and agriculture
- Over 625 currently operational reservoirs, almost 200 more planned
- 41 reservoirs selected for this study
- Built between 2000 and 2017

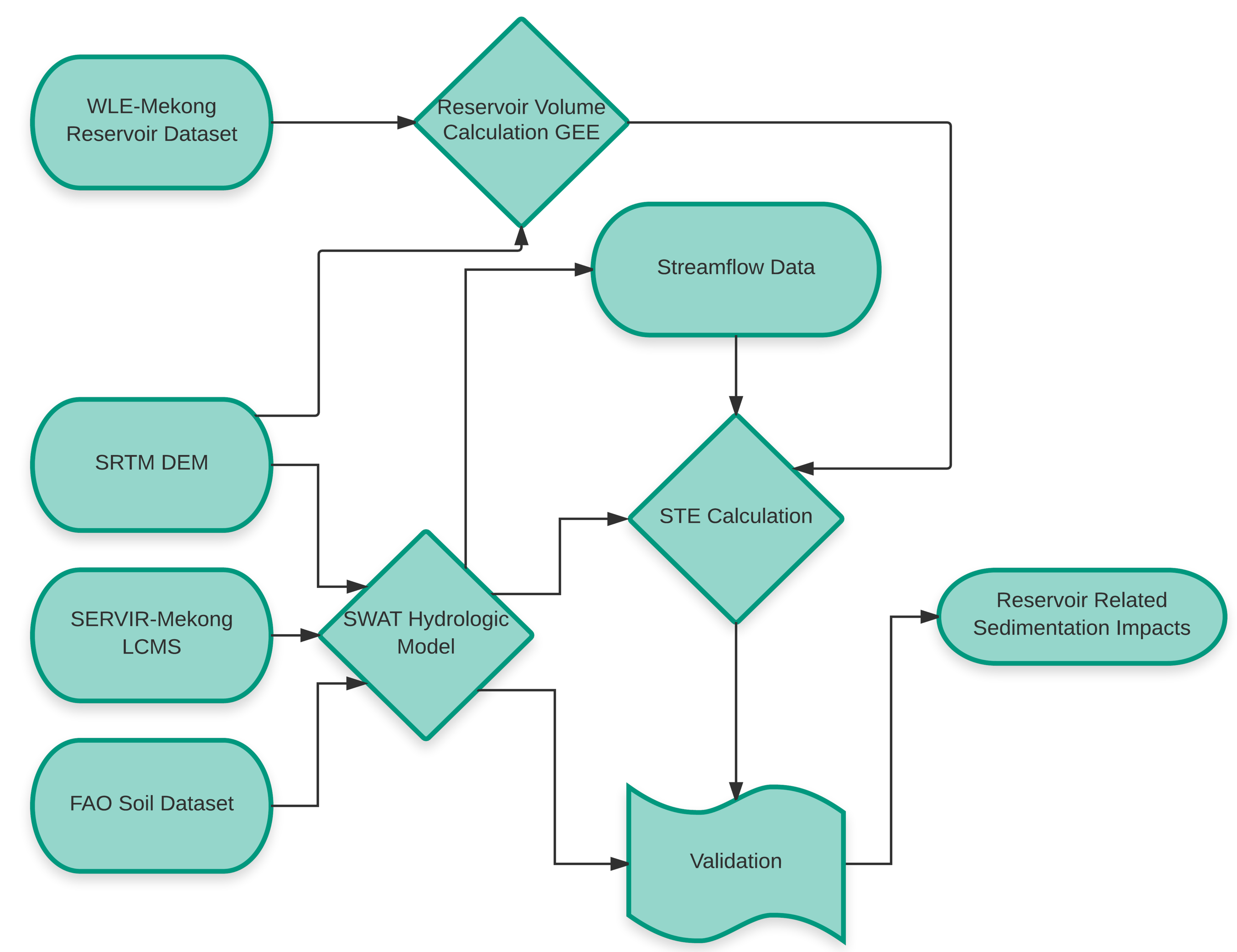


Earth Observations and Input Data

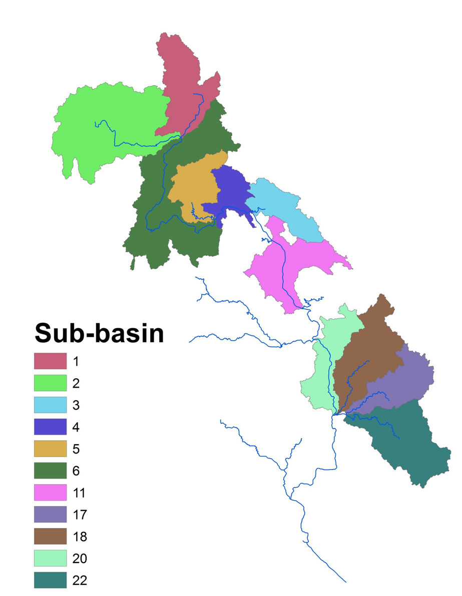
- NASA SRTM Digital Elevation Model
- NASA TRMM precipitation data
- SERVIR-Mekong Land Cover Monitoring System
- ESA Sentinel-1 Synthetic Aperture Radar imagery
- WLE-Mekong Reservoir Dataset
- Mekong River Commission Water Quality Monitoring Dataset



Methodology



1. SWAT Hydrologic Modeling
   1. Gather and reclassify input datasets into SWAT readable format
   2. Delineate watershed and sub-basins
   3. Input soil, slope, and land use rasters
   4. Update weather database and write input tables
   5. Run model from 1975-2100 with 25 year warm-up period to get streamflow and sediment data
2. Reservoir volume calculation on Google Earth Engine
   1. Create buffered polygon around reservoir shape
   2. Filter through Sentinel 1 synthetic aperture radar (SAR) imagery for months dry season (Dec-Mar) and wet season (May-Aug)
   3. Find median SAR pixel value for each season
   4. Apply speckle filter
   5. Examine histogram and set water pixel threshold
   6. Find maximum elevation within each reservoir surface area mask
   7. Subtract DEM value from max elevation and multiply by area of pixel
   8. Find sum of new raster within each reservoir surface area mask
3. Sediment trapping efficiency by sub-basin calculation (Brune, 1953; Kummu & Varis, 2007)
   1. $TE = 1 - \frac{0.5}{\sqrt{\sum_1^j V_i / Q}}$
   2. Find cumulative sum of reservoir volume by sub-basin
   3. Input sub-basin reservoir volume and streamflow data into above equation
4. Validation (ongoing)
   1. Simulation of vertical errors in DEM for volume calculation
      1. Add random value raster to DEM and recalculate volumes
   2. Compare observed values of sediment directly downstream from sub-basins before 2000 to observed sediment after 2017
   3. Compare SWAT output values of sediment to observed sediment from before 2000
   4. Compare SWAT output values of sediment from after 2017 with trapping efficiency values applied to observed sediment from after 2017



Acknowledgements

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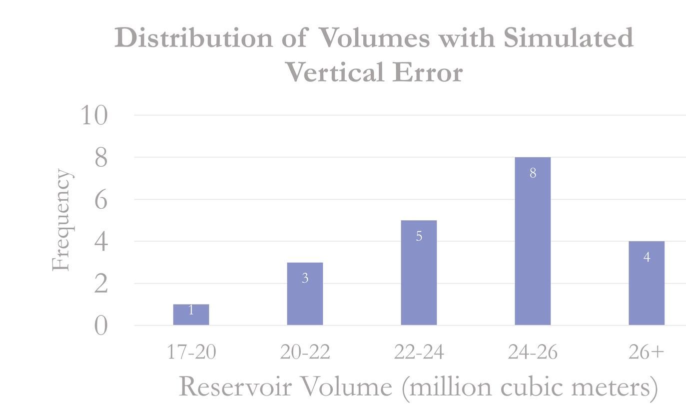
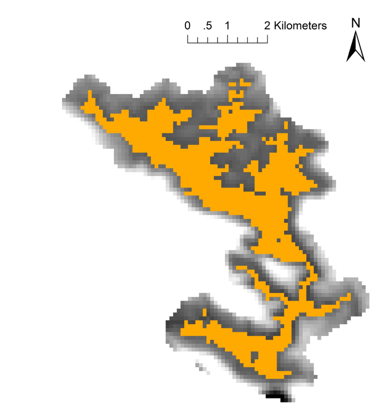
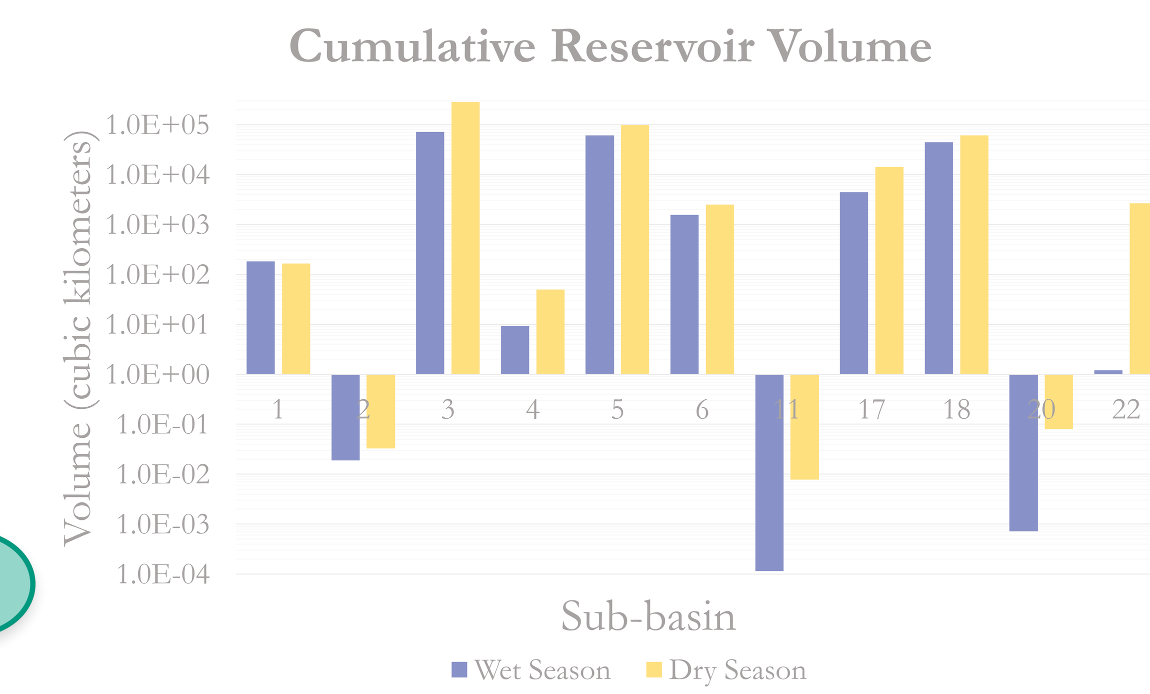
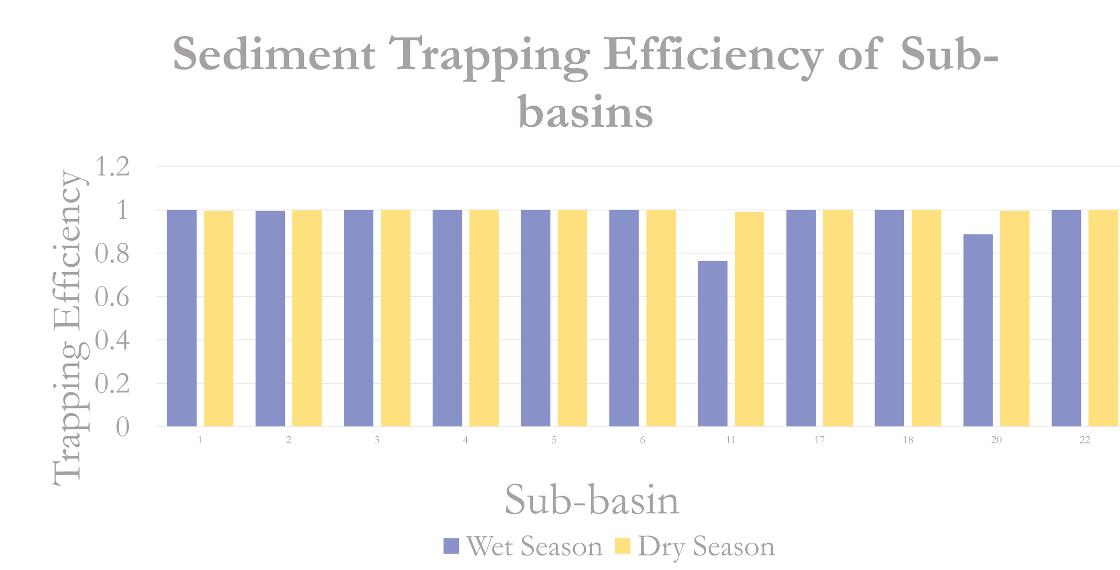
Results





This graph shows the distribution of volumes calculated with DEMs that had simulated errors added for the Nam Mang 3 dam in Laos (shown on the right). The distribution is slightly skewed to the left. The volume calculated using a DEM without simulated errors falls into the modal range of 24-26 million cubic meters.





- Reservoir volume during dry season much higher, but streamflow much lower
- Trapping efficiency higher during dry season
- Trapping efficiency overall close to 100% for most sub-basins

Conclusions

- Streamflow and sediment were modeled using ArcSWAT hydrologic model
- Reservoir volume was calculated using earth observation data on the Google Earth Engine cloud computing platform
- Reservoir volume was found to be higher during the dry season and lower during the wet season, likely due to dam operations for flood/irrigation management
- Sediment trapping efficiency was calculated for 11 sub-basins, but still needs to be validated using in-situ observation data